Plasma based MRI

Sebastian A. Aussenhofer[1] and Andrew G. Webb[1]
[1]*C.J. Gorter Center for High Field MRI, Leiden University Medical Center, Leiden, South-Holland, Netherlands*

Target Audience. Researchers working in RF coil design.

Purpose. All conventional transmit and receive MRI coils are constructed from metal conductors in combination with lumped elements for impedance matching. This fixed geometry, non-reconfigurable design has several implications for practical operation. The transmit components need to be electrically decoupled from the receive elements; the receive elements are always physically present and can shield the RF field from the transmitter, and in hybrid applications such as PET/MRI the RF coils attenuate the PET signal. Here, we present a totally new concept for an MRI coil, which uses reconfigurable conducting plasma rather than a fixed-geometry conductor. A plasma has many advantageous properties in terms of forming an MRI coil, including that the plasma can be turned on-and-off whenever needed (unlike a metal conductor which is always physically present), the resistance of the plasma decreases with increased current passing through the plasma, and the interactions between the precessing magnetization and the plasma can be manipulated by varying the relationship between the plasma frequency (ω_p) and the Larmor frequency (ω_0).

Methods. All experiments were performed using a Philips Achieva whole body 7T MRI system. A four-channel transmit array was constructed from four off-the-shelf fluorescent tubes (Master TL 8W/827, 14 mm diameter, 30 cm length, Osram GmbH, Germany) to generate the plasma. Each fluorescent tube is fed via an L-impedance match circuit to one of the electrodes. A copper shield was constructed around the matching network to minimize the travelling wave contribution to the signal. Equal magnitude transmit signals with 0, 90, 180 and 270^o phase shifts were fed to the four ports of the transmit array. For reception a 32 channel receive array (Nova Medical Inc., MA) was mounted into the plasma transmit array.

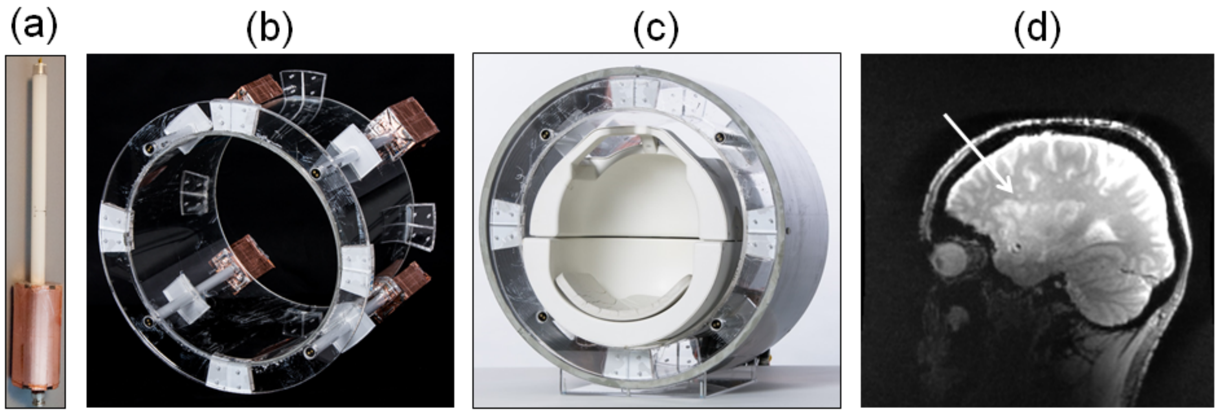

Figure 1. (a) Plasma tube with shielded matching network. (b) Four-channel transmit array with four plasma tubes. (c) Four-element plasma array with 32-channel receive array, (d) gradient echo image from a healthy volunteer at 7 Tesla, with arrow indicating white matter hyperintensities.

Results. Figure 1(d) shows in vivo images of the human brain of a healthy volunteer, acquired with the four element plasma array in transmit mode, and the signal detected using the 32-channel receive array. The images were acquired using a gradient echo sequence with the following parameters: flip angle 15^o, TR 10 ms, TE 5 ms, spatial resolution 1.5 x 1.5 x 1.5 mm, 1 signal average, imaging time 4 minutes 52 seconds. The images show reasonable white/grey matter contrast, and several non-specific hyperintensities can be seen in the white matter.

Discussion. The results of this initial design illustrate the feasibility of using plasmas for MRI even with very simple fluorescent tubes optimized for lighting purposes. Since the plasma turns off before the image data are acquired there is no interaction between the transmit plasma and receive coil array which means that electrical isolation circuits do not need to be included in a plasma transmit array, in contrast to a conventional metallic conductor-based system. Although the images in Figure 1 show fine anatomical details, the efficiency of the current plasma transmit array is lower than that of a commercial transmit coil. SNR comparisons using the oil phantom show that the efficiency is ~25% that of a sixteen-leg high-pass birdcage coil of equivalent dimensions However, this is not surprising given that an off-the-shelf lighting tube has been used. Significant improvements in the plasma performance can be anticipated if a custom-built tube is manufactured. The diameter of the tube can be reduced substantially reducing the power required to ionize the gas, and also the gas pressure reduced. Symmetric central feeding of a two-tube element in a "dipole arrangement" would produce a field more suitable for MRI, particularly at high field (1). With a suitably designed plasma tube we expect that the efficiency will be at least as good as those of a metal-based transmitter, as suggested by results in the related field of plasma antennas (2,3).

References. 1. R. Lattanzi et al. Magn Reson Med 68, 286-304 (2012). 2.J. P. Rayner et al. IEEE Trans Plasma Sci 32, 269-281 (2004). 3. V. Kumar, et al. Prog Electromagn Res Lett 24, 17-26 (2011).